Coho Salmon *(Oncorhynchus kisutch)* Spawner Escapement and Distribution in Redwood Creek, Marin County, CA 1994-2005

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Abstract

The National Park Service began monitoring coho salmon spawning activity in Redwood Creek in 1994, building on previous work by local area visitors and California Department of Fish and Game biologists. From late November through February, NPS biologists and volunteers conduct regular surveys for spawning adult coho, redds, and carcasses. Survey objectives are to: (1) develop an index and/or total escapement estimate of adult coho salmon for the analysis of long-term population trends; (2) determine the distribution of spawning activity by collecting redd location data; (3) determine population characteristics of coho adults including fish size, age, and sex and redd size; and (4) collect tissue and scale samples for genetic and age analysis. The poster presents results of annual escapement, spawn timing and relationship to environmental conditions, spawning distribution and trends on Redwood Creek since 1994-95.

Background

Redwood Creek flows southwest from the flanks of Mt Tamalpais, through Muir Woods National Monument, discharging to the Pacific Ocean through Big Lagoon at Muir Beach. Protected from development, the watershed is occurs within the boundaries of Mt Tamalpais State Park, Golden Gate National Recreation Area and Muir Woods.

Redwood Creek is a 7.5 square mile coastal watershed in southern Marin County and is considered one of the most southerly stable populations of coho salmon (Oncorhynchus kisutch). Redwood Creek supports a genetically distinct sub-group of coho salmon (Garza and Gilbert-Horvath 2003) within the Central California Coast Evolutionarily Significant Unit (CCCESU).

Streams supporting Coho Salmon, Marin County, CA

Methods

Winter surveys are conducted during the coho spawning season to quantify escapement and determine spawning density and distribution. Although surveys focus on coho, occasional stranded spawners and redds are observed and counted incidental to coho observations. Surveys are spaced approximately every week, although storms and high stream flows often dictate less frequent surveys. Teams of two to four observers walk upstream through 2-4 km reaches, along creek margins and banks where possible, and look for live fish, carcasses, and redds. Live fish are identified to species while sex and lengths are visually estimated. Carcasses are measured (fork length), identified to species and sex, and marked to prevent double counting. Carcass scales and tissue samples are collected for age and genetic analysis. Scale samples are only collected from fresh (both eyes are still clear) carcasses that have not been mauled by scavengers. Redds are measured and marked with flagging. Particular care is taken not to disturb redds or actively spawning adults. Locations of all live fish, carcasses and redds are recorded in reference to permanent tags placed every 100 meters along each stream.

The methodologies used in these surveys have been used to estimate escapement for a variety of salmonids throughout the Pacific Northwest (Johnston et al. 1987; Irvine et al. 1992; Anderson and McGuire 1994; Downie and Peterson (undated)).

Since 1994, the NPS has conducted annual surveys along a 7.4 km section of the Redwood Creek mainstem beginning 140 m below the Pacific Way Bridge and ending 500 m above Bridge 4 in Muir Woods. The section encompasses most of the stream length used by coho salmon. To facilitate sampling, the section is divided into three reaches.

Portions of Fern and Kent Creeks, the two largest Redwood Creek tributaries, are also sampled. The reach on Kent Creek extends from the confluence with Redwood Creek to a water fall, approximately 1 km upstream, that is impassable to spawning adults. The Fern Creek section has been surveyed since 1994 and extends between the Redwood Creek confluence and a series of steep cascades 1 km upstream. The debris jam that serves as the upstream limit of surveys on Redwood Creek and the high gradient cascade on Fern Creek are not impassable barriers for steelhead. However, neither coho salmon adults nor juveniles have been observed above these points and they are assumed to be coho barriers.

Watershed Escapement

Adult coho salmon runs within the CCCESU are compressed into a very short window, with upstream migration coinciding with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is typically less than 2 weeks, though the NPS program has documented some individuals to spend up to 20 days in the freshwater under ideal conditions. Our monitoring efforts have shown some years where flows necessary to breach the beach interface, allowing entry into the watershed, did not occur until mid-January. In other years, rains in November have resulted in flows that would allow coho access to the watershed. Even when the early entry opportunity has occurred in November, little spawning activity has been observed. For the most part, peak of spawning within Redwood Creek is between mid-December and mid-January. Typically the peak count will follow a large flow event.

Spawner Years

| Year	Number of Surveys	Survey Length (km)	PLD Index	Total Carcasses	Total Redds	Source
1969		3.2	24	4	--	CDFG
1977-78	1	3.2	36	3	--	CDFG
1985-86	1	7.2	50	--	--	CDFG
1994-95	5	8.4 [a]	58	22	--	NPS Fong 1995
1995-96	5	8.4 [a]	27	18	--	NPS Fong 1996
1996-97	6	8.4 [a]	57	15	--	NPS Fong 1997
1997-98	7	9.4 [b]	65	30	80	NPS Manning 1999
1998-99	11	9.4 [b]	39 [c]	10	58	NPS CSRP
1999-00	6	8.4 [a]	10	1	7 [*]	NPS CSRP
2000-01	5	9.4 [a]	49	13	35	NPS CSRP
2001-02	5	9.4 [b]	105 [d]	63	47	NPS CSRP
2002-03	5	9.4 [b]	24 [e]	3	7 [*]	NPS CSRP
2003-04	6	9.4 [b]	67	25	43	NPS CSRP
2004-05	7	9.4 [b]	171 [f]	76	93	NPS CSRP

a – Includes the main stem of Redwood Creek, Fern Creek, and Kent Creek
b – Includes the main stem of Redwood Creek, Fern Creek, and Kent Creek
c – Includes two peaks, 7 weeks apart
d – Includes two peaks, 2 weeks apart
e – Includes two peaks, 33 days apart
f – Includes two peaks, 25 days apart
* – Poor survey conditions resulted in low observer efficiency

The number of live adult coho salmon, carcasses, and redds were surveyed annually in the Redwood Creek watershed from spawner years 1994-95 thru 2004-05. One time spawner surveys were also conducted during spawner years 1969, 1977-78, and 1985-86. To facilitate comparisons between years, the live adult coho numbers are presented as the Peak Live plus cumulative Dead (PLD) minimum spawning escapement index.

Redd Location and Distribution

Year Class 1

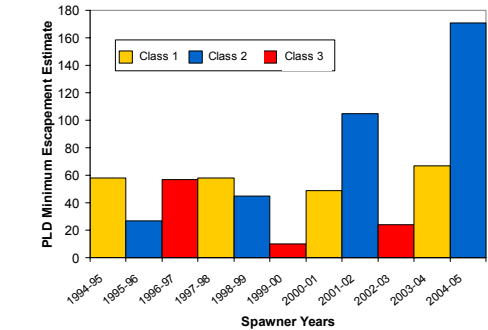
Year Class 2

Year Class 3
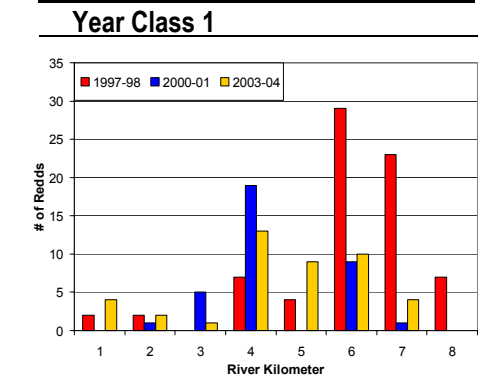
In both YC2 and YC3, redd densities were highest in river kilometers five and six. Coincidentally, river kilometers five and six correspond with the main visitor access areas of Muir Woods. Spawning densities in YC1 are more dispersed with peak redd numbers occurring four kilometers upstream from the start of the survey in both 2000-01 and 2003-04 spawning seasons. Like YC2 and YC3, the 1997-98 spawner season in YC1 had peak redd densities in Muir Woods.

Year Class 1

Year Class 2
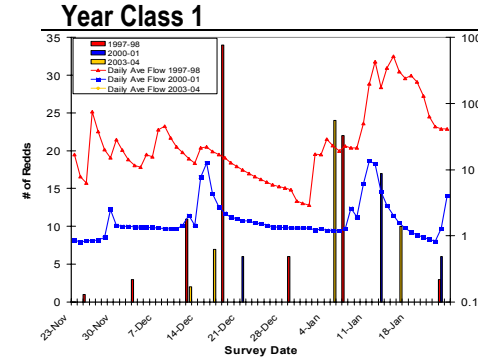
Year Class 3

Graphics represent the daily average flow and corresponding coho redd survey results for the three coho year classes. Coho redd size characteristics (below by year class) including measured redd length, measured redd width and calculated redd area from Redwood Creek spawner surveys, winter 1997-98 through 2004-05.
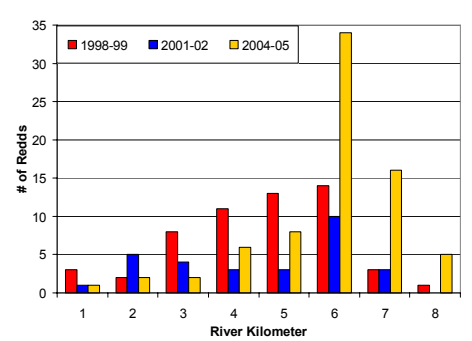
Coho Salmon PLD Index Escapement results beginning winter 1994-1995 through winter 2004-2005. The three year classes are represented as colors (gold [YC1], blue [YC2], and red [YC3]) to show relationships between spawning runs. YC2 shows an increasing trend in PLD over the last four generations. The other strong year class (YC1) has resulted in consistent PLD (50-70 coho) through four generations. YC3 is the weakest year class, with low escapement compounded by poor survey conditions.

Coho salmon spawning survey Area Under the Curve (AUC) and Peak Live plus cumulative dead (PLD) escapement estimates for Redwood Creek were determined for spawning seasons 1997-98 thru 2004-05. The AUC range reported in literature assumes an observer efficiency (OE) of 70-80 % and a residence time (RT) of 10-13 days. In all years the AUC escapement estimate range exceeds the PLD escapement estimate.
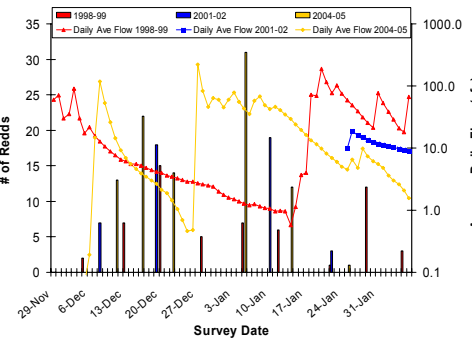
Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Length (km)	AUC Range 100% OE [1] RT 8-17 days	AUC Range 50% OE [2] RT 8-17 days	AUC Range for OE & RT reported in literature	Redwood Creek PLD
1997/98	7	23 Nov 97	7.5	9.4	89-188	177-376	145-195	65
1998/99	11	29 Nov 98	8.6	9.4	39-83	78-167	64-87	39 [a]
1999/00	6	1 Jan 00	11.8	8.4	8-17	16-35	13-18	10
2000/01	5	15 Dec 00	13.0	9.4	74-157	148-314	121-163	49
2001/02	5	7 Dec 01	11.3	9.4	116-247	233-494	190-257	105 [b]
2002/03	5	10 Dec 02	14.0	9.4	22-46	43-92	35-48	24 [c]
2003/04	6	11 Dec 03	6.3	9.4	43-91	86-182	70-94	67
2004/05	7	6 Dec 04	8.3	9.4	169-359	338-718	276-373	171 [d]

a- Includes two peaks, 7 weeks apart
b- Includes two peaks, 22 days apart
c- Includes two peaks, 33 days apart
d- Includes two peaks, 25 days apart

Coho Population Characteristics

			Live Coho				Carcasses		
		#	%	Mean FL	FL SD	#	%	Mean FL	FL SD
97-98	M	12	26	57.9(n=12)	5.42	6	25	66.0(n=3)	6.56
	F	24	52	56.9(n=24)	4.85	7	29	54.8(n=6)	4.07
	J			40.0(n=4)	0.00	4	17	39.7(n=7)	1.25
	Unk	6	13	53.3(n=6)	4.08	7	29	60(n=2)	7.07
	All	46	100			24	100		
98-99	M	8	22	61.3(n=8)	3.54	2	14	62.0(n=2)	2.83
	F	16	44	53.8(n=16)	3.87	6	43	52.3(n=6)	2.58
	J	6	17	36.7(n=6)	5.16	5	36	42.2(n=5)	2.59
	Unk	6	17	55.0(n=6)	4.47	1	7		
	All	36	100			14	100		
99-00	M	3	33	56.7(n=3)	11.55	0	0		
	F	4	44	62.5(n=5)	11.9	1	100	55.0(n=1)	
	J	0	0			0	0		
	Unk	2	22	67.5(n=2)	3.54	0	0		
	All	9	100			1	100		
00-01	M	4	9	60.0(n=4)	7.07	3	23	62.5(n=2)	3.54
	F	14	30	55.0(n=14)	4.39	6	46	66.8(n=5)	2.94
	J	28	61	39.1(n=28)	4.31	3	23	42.7(n=3)	4.62
	Unk	0	0			1	8	55.0(n=1)	
	All	46	100			13	100		
01-02	M	52	56	59.2(n=51)	8.25	19	37	70.1(n=19)	6.31
	F	31	33	56.5(n=30)	6.34	20	38	65.4(n=20)	5.28
	J	1	1	45.0(n=1)		0	0		
	Unk	9	10	57.1(n=7)	6.99	13	25	64.9(n=7)	4.6
	All	93	100			52	100		
02-03	M	2	13	65.0(n=2)	7.07	0	0		
	F	10	67	53.6(n=7)	3.78	1	20	50.0(n=1)	
	J	2	13	42.5(n=2)	3.54	4	80	36.5(n=4)	8.19
	Unk	1	7	55.0(n=1)		0	0		
	All	15	100			5	100		
03-04	M	19	32	62.0(n=19)	6.96	10	36	63.8(n=8)	7.32
	F	26	43	59.6(n=25)	5.13	13	46	62.2(n=12)	5.39
	J	13	22	35.4(n=13)	6.91	2	7	40.5(n=2)	0.71
	Unk	1	2	55.0(n=1)		3	11	64.0(n=2)	1.41
	All	59	98			28	100		
04-05	M	69	40	65.1(n=68)	5.50	18	26	67.2(n=15)	4.68
	F	82	48	60.1(n=78)	5.13	40	58	63.3(n=40)	4.78
	J	9	5	38.3(n=9)	2.50	1	1	70.0(n=1)	
	Unk	11	6	60.6(n=8)	6.23	10	14	49.0(n=1)	
	All	171	100			69	100		

Sex ratios (Males, Females, Jacks, and Unknown sex) and size observations of live coho observed during peak spawning surveys and carcasses from Redwood Creek spawner surveys, winter 1997-98 thru 2004-05. In most years, mean observer length appears to be similar to the mean carcass length. Observer lengths can thus be used to characterize the length distribution of each run.

CCCESU Coho Genetics

During spawner surveys, tissue and scale samples are collected from fresh carcasses (eyes clear) for genetic and age analysis. Garza and Gilbert-Horvath (2003) released a phylogeographic tree which estimated the frequency of 401 alleles using the Cavalli-Sforza/Edwards Chord distance bootstrap method for genetics information in the CCCESU. The results depict the presence of five genetic subgroups within the ESU that are geographically and oceanographically based. This includes:

- Santa Cruz County subgroup which shows some influence from the Noyo stock;
- Redwood/Pine Gulch Creek subgroup which does not show genetic relationship with any other CCCESU coho;
- Lagunitas/Olema subgroup (potentially Tomales Bay) which shows an influence from the Noyo River stock;
- Russian River Green Valley subgroup which does not show genetic relationship with any other CCCESU coho;
- Northern watersheds subgroup including the Noyo and the Pudding Rivers.

Developing a Regional Index

Developing a system of metrics to describe fishery response between sub-populations can help determine the relative health of a watershed. These Redwood Creek data are compared to other systems using redd density. Consistent methodologies across watersheds would facilitate development and use of watershed and regionally based metrics to compare coho populations.

Years	Lagunitas Creek Mainstem			San Geronimo Creek Mainstem			Devil's Gulch Mainstem			Olema Creek Mainstem			Redwood Creek Mainstem		
	Total Redds	Survey Length (km)	Redd Density #/km	Total Redds	Survey Length (km)	Redd Density #/km	Total Redds	Survey Length (km)	Redd Density #/km	Total Redds	Survey Length (km)	Redd Density #/km	Total Redds	Survey Length (km)	Redd Density #/km
1997-98	80	10.7	7.5	107	7.0	15.3	52	3.2	16.3	126	13.4	9.4	74	7.4	10.0
1998-99	92	10.7	8.6	46	7.0	6.6	32	3.2	10	42	11.6	3.6	55	7.4	7.4
1999-00	139	10.7	13.0	98	7.0	14.0	19	3.2	6.0	7.2	1.4	7	7.4	0.9
2000-01	119	12.8	9.3	96	7.0	8.0	11	3.2	3.4	86	11.4	7.6	35	7.4	4.7
2001-02	79	12.8	6.2	102	7.0	14.5	59	3.7	16.1	58	11.6	5.0	74	7.4	10.0
2002-03	71	12.8	5.5	39	7.0	5.6	24	3.7	6.6	5	11.6	0.4	5	7.4	0.7
2003-04	124	12.8	9.7	139	7.0	19.8	48	3.7	13.1	88	11.6	7.6	43	7.4	6.0
2004-05	120	12.8	9.4	138	7.0	19.7	112	3.7	30.6	92	11.6	7.9	74	7.4	10.0

Coho spawning survey redd densities were calculated for mainstem Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Olema Creek, and Redwood Creek from spawner seasons 1997-98 through 2004-05. Both Olema Creek and Redwood Creek appear to have much lower redd densities than Lagunitas Creek, San Geronimo Creek and Devil's Gulch.

References

Anderson, D. and H. McGuire. 1994. Redwood Creek basin 1991-1992 spawning and carcass survey, annual report. Unpublished report. National Park Service, Redwood National Park. Arcata, CA.

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. North American Journal of Fisheries Management 14:237-261.

Collins, Barry W. (editor) 2003. Interim restoration effectiveness and validation monitoring protocols, California Coastal Salmonid Restoration Monitoring and Evaluation Program. March 2003, p. 320. California Department of Fish and Game. http://www.dfg.ca.gov/nafwb/2003/200303_Interim_Protocol_Manual.pdf

Downie, S. and G. Petersen. undated. Spawning Inventory. California Department of Fish and Game unpublished instructions for conducting spawner surveys.

Garza, C. and Gilbert-Horvath. 2003. Report on the genetics of coho salmon (Oncorhynchus kisutch) held at the Warm Springs (Don Clausen) Hatchery for recovery efforts in the Russian River. NOAA Southwest Fisheries Science Center. Santa Cruz Laboratory. 15pp.

Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1987. Instream indexing of coho salmon (Oncorhynchus kisutch) escapement in French Creek, British Columbia. Canadian Technical Report of Fisheries and Aquatic. No. 1573.

Irvine, J. R., R. C. Bocking, and K. K. English, and M. Labelle. 1992. Estimating coho salmon (Oncorhynchus kisutch) escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. Canadian Journal of Fisheries and Aquatic Sciences 49: 1972-1981.

Manning, D.J. 1999. Coho and Steelhead Restoration Project Annual Coho Salmon Spawner Survey Report: 1997-98. Coho and Steelhead Restoration Project. PORE-NR-WR-99/01. 45 pp. plus appendices.

Acknowledgements

Redd size characteristics tables (by year class)

Year	Redd Length				Redd Width				Calculated Redd Area			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
1997-98	0.5	3.0	2.1(n=80)	0.9	0.3	1.0	1.1(n=80)	0.5	0.2	12.0	2.7(n=80)	2.2
2000-01	0.5	7.0	2.3(n=35)	1.2	0.3	1.0	1.0(n=35)	0.3	0.3	10.5	2.7(n=35)	1.9
2003-04	1.0	8.0	3.1(n=40)	1.6	0.9	3.8	1.8(n=40)	0.8	1.0	24.1	6.8(n=40)	5.8

Year	Redd Length				Redd Width				Calculated Redd Area			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
1998-99	0.7	4.0	1.8(n=58)	0.7	0.4	3.0	1.0(n=58)	0.4	0.2	6.8	2.0(n=58)	1.5
2001-02	0.8	2.8	1.7(n=44)	0.6	0.4	1.5	1.0(n=44)	0.3	0.3	4.1	1.8(n=44)	1.0
2004-05	1.2	4.6	2.4(n=91)	0.8	0.5	3.0	1.3(n=91)	0.4	0.4	12.0	3.2(n=91)	1.8

Year	Redd Length				Redd Width				Calculated Redd Area			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
1999-00	2.0	2.5	2.9(n=7)	2.3	1.1	8.8	1.7(n=7)	0.5	2.1	8.8	5.2(n=7)	2.3
2002-03	1.3	4.5	3.3(n=4)	1.5	1.0	2.8	1.8(n=4)	0.8	1.3	12.6	6.1(n=4)	4.8